

# Assessing Wood-Energy Pricing Policies in Urban Ouagadougou (Burkina Faso)

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## Abstract

Burkina Faso has been running many interventions in the energy sector over the last decades. Still, there is a dearth of reliable and ready available price and income elasticities of demand to base these on, especially for domestic use of traditional fuels. The paper uses an Almost Ideal demand system (AIDS) model to explain the failures of wood-energy pricing and substitution policies. With the consumers' preferences strong separability assumption, income elasticities of AIDS model are estimated; the use of the formula of Frisch (1959) allowed computing own- and cross-price elasticities. A relative inelasticity is observed for wood-energy demand compared to households income and fuel price. This low sensitivity of the wood-energy compared to its own price and households' income confirms the strong dependency of these households to fuel wood. Moreover, Hicksian cross price elasticities between wood-energy and other fuels reveal substitution relations. The low income and own- and cross-price elasticities of wood-energy explain why substitution and price policies do not operate well and have a very weak impact on the fall in the demand of the wood-energy.

## Keywords

Wood-energy; Kerosene; LPG; Income and Price Elasticities; Price Policy

## Introduction

The natural resources' degradation has become the subject of increasingly studies over last decades. Human consumption of natural resources is generally identified as the main link between human behavior and degradation of the natural environment (Stern, Dietz, Ruttan, Socolow and Sweeney, 1997). Many studies have investigated the households' energy demand focusing on the transition away from biomass fuel toward more cleaner alternative energy sources (Macht, Axinn and Ghimire, 2007; Rajmohan and Weerahewa, 2007; Ouedraogo, 2006a), emphasizing the hypothesis of energy ladder. The demand of firewood is considered in many poor countries as the main source of domestic energy as well in rural areas than

urban ones (Cecelski, Dunkerley and Ramsay 1979; Heltberg, Arndt and Sekhar 2000; Ouedraogo, 2002, 2006b).

The International Energy Agency (2005) reported that more than 2.4 billion people rely directly on traditional biomass fuels for their cooking and heating and stated that biomass use in poor countries represents over half of residential energy consumption. Other studies showed that the demands for fuelwood by subsistence agricultural households may be the leading cause of world deforestation (Amacher, Hyde and Joshee 1993; Amacher, Hyde and Kanel 1996). According to the United Nations' Food and Agriculture Organization (2005), the global rate of deforestation continues to be alarmingly high stated to 13 million hectares per year. Nowadays, deforestation is considered as a global problem because of the perception that the earth's resources are reaching the limits for supporting the world's population and economic systems and of its consequences on climate changes (Schmink, 1994). Deforestation has created a situation of fuelwood scarcity to the point that an impending "fuelwood crisis" looms in many settings (Deweese, 1989; Heltberg, Arndt, and Sekhar, 2000).

For sub-Saharan Africa, Sow (1990) noticed that wood-energy provides most of the energy consumed and that many people today do not have enough wood to cook more than one meal per day. For these people, the real energy crisis is the lack of wood-energy. Ten years ago, Chavin (1981) published a book titled "Une ville africaine en crise d'énergie"<sup>1</sup> referring to Ouagadougou, the capital city of Burkina Faso, to underline the cooking energy crisis.

The Burkina Faso residential energy consumption mainly relies on wood-energy, kerosene, liquefied petroleum gas (LPG) and electricity. Wood-energy remains the main source of the households cooking energy and of a significant part of the craftsmen so

<sup>1</sup> An African City in Energy Crisis

that since the Seventies, the demand for this fuel was perceived like an accelerating factor of deforestation and turning into a desert. In this country, wood energy has contributed to the national energy balance of a mean value of 74,94% in 2008; this contribution is higher for households energy consumption that reached the proportion of 94,79% for the same year (Department of Environment, 2010). Many policies have been implemented by public authorities to decrease household wood-energy consumption and to substitute it by alternative cleaner fuels. But despite all these policies, the depletion rate of forest resources is still alarming. In recent years, depletion of resources have resulted in an increase of direct and indirect costs (FAO, 2003). During the last two decades, reforms on the means of control and regulation of the exploitation and the marketing of the forest resources allowed the implementation of a certain number of forest management instruments. These reforms led to the modification of the price pattern of wood-energy respectively in 1995 and 1998. Since 1985, the prices of the firewood were fixed by the government. This firewood's prices administration is primarily active upstream of the commodity chain on the managed forest level, and consisted to introduce (and/or increase) eco-taxes and to increase the woodcutters' remuneration. The real prices of the wood-energy (firewood and charcoal) kilogram passed from 2.1 FCFA<sup>2</sup> in 1970 to 15 FCFA in 1980, to 25 FCFA in 1985, then to 35 FCFA in 1995 (INSD, 1969-1996). In spite of the wood-energy prices rise, its domestic demand is accentuated and its substitution's policies remain negligible. All occurs as if the pricing policies have no significant impacts neither upstream (supply side), nor downstream (demand).

In such context where pricing and substitution policies seem to have no significant effect on substitution of firewood by more cleaner sources of cooking energy, identifying and assessing the causes of the failures of these policies are necessary to help correcting these policies. So, The main objective of this paper is to estimate and analyse the income and price elasticities of households' demand for different kinds of fuels in urban Burkina Faso, using a cross section data on urban household for year 1996 and an Almost Ideal Demand System (AIDS) model, while imposing the assumption of utilities additivity on the households' expenditures. Instead of income we consider the total household expenditure as a proxy.

Many researches on households' residential energy demands have been analyzed theoretically and empirically using different approaches. These studies include the energy ladder hypothesis (Rajmohan and Weerahewa, 2007; Kebede et al., 2002; Arnold et al., 2006; Davis, 1998; Masera et al., 2000; Barnett, 2000; Hosier, 1988; Campbell, Vermeulen, Mangono and Mabugu, 2003), the Engle curves (Amacher et al., 1993, 1996, 1999; Mekonnen, 1999; Helberg et al., 2000; Gundimeda and Kohlin, 2003; Baland et al., 2005; Blanciforti, Green, Gordon, 1986) and energy demand functions (Athukorala et al., 2007; Erdogdu, 2006). In these studies, many different factors have been considered to have direct influence on the energy demand patterns according to the context. They have analyzed the energy demand both at micro and macro levels where the impacts of income and price on the energy demand were of main interest; many other factors are supposed to influence the households energy demand (households size, characteristics of households housing, community context, Connection to power, etc...). Discussion of the impacts of income and price on the energy demand were of main interest in these studies, while extensions were made to study other factors that influence the energy demand. The studies that most resemble our own approach are those of Gundimeda and Kohlin (2003, 2006), and Rajmohan and Weerahewa (2007) who have respectively used a Linear Approximate Almost Ideal Demand System (LA-AIDS) and an Almost Ideal Demand System (AIDS) model to estimate Engel curves and price elasticities of household demand for different kinds of fuels in India and Sri Lanka.

We first present the AIDS model functional specification under the additivity assumption of preferences, then the data used and some descriptive analysis showing the relationship of the household cooking energy with the standards of living and household size. Next, we present the results of estimates and analysis relating thereto, and finally deliver the findings and their policy implications

#### Aids' Model Specification under the Assumption of Additivity of the Utilities

The implementation of the AIDS model aims at identifying and evaluating the determinants of the households' demand through the calculation of price and income elasticities, with the possibility of deriving the hicksian demands functions. Paraphrasing Sadoulet and De Janvry (1995, page 41), "three systems of demand received a considerable attention because of

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<sup>2</sup> 1 EURO = 655.957 FCFA

their empirical relevance. It is about the model "Linear Expenditure System (LES)" developed by Stone (1954), the model "Almost Ideal Demand System (AIDS)" developed by Deaton and Muellbauer (1980), and the combination of these two systems in a model says "Generalized Almost Ideal Demand System (GAIDS)". Other complete systems of demand found in the literature are the Rotterdam model by Theil (1976) and Barten (1969). The translog functional form is promoted by Christensen, Jorgenson, and Lau (1975).

Because of the nonobservance of the prices in this study's data set, the use of the LES model is excluded, since this model cannot provide inferior goods. However, we suppose that some of the targeted goods can be inferior. We thus chose the AIDS model of Deaton and Muellbauer (1980; 1994) since this model makes it possible to have all the categories of goods defined by the economic theory. As Prais and Houthakker (1955) underlined it, the functional form used by AIDS model provides from an empirical point of view, more powerful outcomes than those of the linear, double logarithmic and reciprocal logarithmic functional forms.

The basic objective of consumer theory is to explain how a rational consumer chooses what he will consume when he is confronted with various prices and limited income (De Janvry and Sadoulet, 1995). Let us consider an individual whose utility function is  $u(q, z)$ , where  $q$  is the vector of quantities  $q_i$  of  $n$  goods on which a decision of consumption will be made,  $z$  the personal sociodemographic characteristics of the consumer. The amount of income that the consumer can spend is  $y$ , imposing a budget constraint  $p'q=y$ , where  $p'$  is the vector of  $n$  corresponding price. The objective function of the consumer is to maximize its utility function under the constraint of income  $p'q=y$ , so  $y$  is the total expenditure considered as a good proxy of households income (Deaton and Muellbauer, 1980; De Janvry and Sadoulet, 1995). This can be written as follows:  $\text{Max } u(q, z) + \lambda(p'q-y)$ , where  $\lambda$  is the Lagrange multiplier.

The basic AIDS model is specified as follows:

$$w_i = \alpha_i + \sum_j \gamma_{ij} P_j + \beta_i \log\left(\frac{y}{P^*}\right) + \sum_h \delta_{ih} z_h + \varepsilon_i \quad (1)$$

$P^* = \sum_i w_i \ln p_i$  being an approximation of a price index  $w_i$  and  $p_i$  being respectively the budget shares and the price of  $i^{\text{th}}$  good.  $w_i = p_i q_i / y$  where  $q_i$  is the quantity consumed of  $i^{\text{th}}$  good.

$w_i$  being budgetary shares of the various goods or

groups of goods defined under the assumption of strong separability,  $\gamma_{ij}$  parameters relating to the  $P_j$  prices of the other goods referring to ( $i \neq j$ ),  $y$  the total expenditure,  $z_h$  being characteristics of the household,  $\delta_{ih}$  parameters relating to the characteristics of the households and  $\varepsilon_i$  residues of the regression. Since our data base does not contain observations on the prices of the various goods (the  $\sum \gamma_{ij} P_j$  should be dropped from equation (1) and  $P^*=1$ ), thus, the adapted form of AIDS model is reduced to the Engel curves in this form:

$$w_i = \alpha_i + \beta_i \log(y) + \sum_h \delta_{ih} z_h + \varepsilon_i \quad (2)$$

The Engle curve explains the relationship between the quantity of a good demanded and the income of the consumer, keeping all the prices held constant levels. Budget (expenditure) elasticities calculated using the coefficients estimated in the Engle function, are free measures of responsiveness of quantities demanded to a change in the total budget. They are used to categorize commodities as inferior goods, necessities or luxuries. They must satisfy several properties which are:

- a) the budgetary constraint or Engel's aggregation;
- b) the capacity to represent all the categories of goods (primary, luxury and inferior);
- c) and when the income elasticity increases, the goods' high consumption should tend towards a saturation's point.

This enables economists make meaningful comparisons at various contexts.

Differentiating equation (2) with respect to  $y$  gives the expenditure or budget elasticities ( $\eta_i$ ) in equation (3) below:

$$\partial w_i / \partial y \Rightarrow \eta_i w_i - w_i = \beta_i \Rightarrow \eta_i = 1 + \frac{\beta_i}{w_i}, w_i = \frac{p_i q_i}{y} \quad (3)$$

In this precise case where the price variables were not observed in the dataset, the traditional methods of estimation are powerless to estimate price elasticities. However, from the recent developments of the demand models, a possibility exists with the utility separability assumption to exceed this problem. The concept of separability postulates that the goods which intervene together in the formation of the utility can be gathered together, in the same way, those which intervene only in one general direction through the budgetary constraint can also be put together (De Janvry and Sadoulet, 1995). Several types of separabilities were postulated, the certain more restrictive ones than the others [(Frisch, 1959);

(Houthakker, 1960); (Brown and Deaton, 1972); (Deaton and Muellbauer, 1980; 1992); (L Phlips, 1990)].

The weak separability assumption implies that the function of direct utility [(Deaton and Muellbauer, 1994, p. 127), (Decoster and Vermeulen, 1998, p. 3) ], can be written in the following form:

$$u = u(q) = f[u_1(q_1), \dots, u_G(q_G), \dots, u_N(q_N)] \quad (4)$$

Where,  $u$  is a quasi concave, differentiable and increasing function;  $q$  the vector of the goods,  $f$  is an increasing function and  $u_1, u_2, \dots, u_N$  are related to utility respectively vectors  $q_1, q_2, \dots, q_N$  which are groups of goods. As Deaton and Muellbauer (1992, p. 122) underline it, there is no reason that the utility functions  $u_i$  do not contain several groups of goods or that they contain one good. The utility function of the form of the preceding equation will give rise to Marshallian demand functions on two levels of budgeting for all goods  $i$  of the group  $G$  as follows:

$$q_i = g_{G_i}(y_G, p_G) \quad (5)$$

Where  $y_G$  is equal to the total expenditure of the group of goods  $G$  and  $p_G$  is the vector of price in the group. These demands on two levels of budgeting are the result of the maximization of  $v_G$  under the constraint of  $\sum p_i q_i = y_G$ , where  $q_i$  is an element of the set  $G$ . These demands have the usual properties of the demand functions since they are derived from a standard form of procedure of the utility maximization. The assumption of budgeting on two levels implies that the consumer initially allocates shares of his budget to the various groups of goods (food goods, energy goods, durable education, health, goods, etc...); and that in the second time, it carries out one second allowance on behalf of budget of each group to the various goods of the group which it decides to consume. The lack of observations on the variables price does not enable us to use this assumption which would have supported an analysis exclusively on the group of cooking<sup>3</sup> energies: what would have enabled us to describe more effectively the relations than maintain these energies cooking between them.

The most restrictive separability, traditionally used in the empirical plan is introduced by Frisch (1959): each good belongs to a given group, it is strong <sup>4</sup>

separability. This concept also will contribute to reduce the number of parameters to be estimated in the systems of demands. Thus, the additivity of the preferences is a particular case of strong separability. The function of total utility is written in this case as follows (De Janvry and Sadoulet, 1995, p. 36):

$$U = u_1(q_1) + u_2(q_2) + u_3(q_3) + \dots + u_n(q_n) \quad (6)$$

That means the marginal utility ( $MU_i$ ) of a good  $i$  is independent of the quantity consumed of an unspecified other good  $j$ :

$$MU_i = \frac{\partial u}{\partial q_i} = \frac{du_i}{dq_i}, \text{ et } \frac{\partial MU_i}{\partial q_j} = 0 \quad (7)$$

"The necessary and sufficient criterion for a function to be separable is that the marginal rate of substitution between two variables belonging to the same group is to be independent of the values of the variables belonging to other groups" (Phlips, 1990, p. 68). But with the question of knowing "if in particular, additivity is not a so strong condition, i.e. if the aggregation of the goods is possible without supposing the independence of the various groups of goods?", Phlips (1990, p. 66-67) answers that this is possible because independence between the marginal utilities of the various groups of goods does not imply inevitably that the demand for a group of goods or a good  $i$  does not affect that of another group of goods or a good  $j$ . The assumption of strong separability and in particular that of additivity of the preferences interests us because not only it makes it possible to disaggregate certain groups of goods, but also it supports the calculation of price elasticities in the specific case where the dataset allows the use of the Frisch (1959) formula. Phlips stresses that strong separability is a condition so strong that it implies weak separability. De Janvry and Sadoulet (1995, pp. 52-59) assumed the utility additivity which allows to disaggregate certain groups of goods as well as possible and to estimate the Engel curves and the direct and cross-price elasticities on Morocco's rural households. We will thus estimate in the same way the Engel curves, the direct and cross-price elasticities on the households of Ouagadougou. "The advantage of the strong separability or the additivity of the preferences is that the only knowledge of the income elasticity and the currency flexibility allows estimating price elasticities. Thus, the econometricians do not need more relative variations on the goods' prices to

<sup>3</sup> The use of the weak separability implies an optimization of the utility under budgetary constraint, which implies the use of observations on the various goods prices.

<sup>4</sup> Basic references: Frisch (1959) and Houthakker (1960). According to L. Phlips (1990, p. 70-71), "the strong separability formally implies the additivity of the utilities

and it is only when each group of goods includes only one, thus the strong separability is reduced to the additivity assumption".

estimate these elasticities" (Deaton and Muellbauer, 1994, p. 138). Thus with the assumption of strong separability or additivity of the preferences, goods and groups of goods own- and cross-price elasticities ( $\varepsilon_{ii}$  and  $\varepsilon_{ij}$ ) are related to expenditure or budget elasticities ( $\eta_i$ ), budget shares ( $w_i$ ) and money flexibility ( $\omega$ ) are given by equation (8) below:

$$\varepsilon_{ij} = -\frac{w_j}{\omega} \eta_i \eta_j - w_j \eta_i, i \neq j, \quad (8)$$

$$\varepsilon_{ii} = \frac{1}{\omega} \eta_i (1 - w_i \eta_i) - w_i \eta_i, \text{ or } \omega = \frac{\partial \lambda}{\partial y} \frac{y}{\lambda}$$

$\omega$ , the "flexibility of the currency",  $\eta_i$  budget elasticities and  $\lambda$  marginal utility of the income to the optimum. Price elasticities are a function of the budgetary shares, budget elasticities and the parameter  $\omega$  (De Janvry and Sadoulet, 1995, p. 36). The Marshallian demand function is the solution of a utility maximization programme under budgetary constraint. Elasticities resulting from the ordinary demands in their turn will make it possible to derive the functions from hicksian demand starting from the equation of Slutsky which makes it possible to empirically connect the marshallian demands to the hicksian demands:

$$\frac{\partial q_i(p, y)}{\partial p_j} = \frac{\partial h_i}{\partial p_j} - q_j \frac{\partial q_i(p, y)}{\partial y}$$

$$\Rightarrow \frac{\partial h_i}{\partial p_j} = \frac{\partial q_i(p, y)}{\partial p_j} + q_j \frac{\partial q_i(p, y)}{\partial y}, \quad (9)$$

Where  $h_i$  is the hicksian demands and  $q_j$  the marshallian demands. In terms of elasticity, the equation of Slutsky is written as follows:

$$\varepsilon_{ij}^* = \varepsilon_{ij} + w_j \eta_i \quad (10)$$

Where,  $\varepsilon_{ij}^*$  are compensated price elasticities and  $\eta_i$  the budget elasticity of the goods  $i$ . Thus, compensated elasticities become function of marshallian elasticities and the budgetary shares (Hal R. Varian, 1992).

### Data Set and Households' Characteristics

The dataset is based on an extensive survey on household expenditure in Ouagadougou, collected within the framework of the project of the harmonization of consumer price indices in the seven member countries of the West African Economic and Monetary Union (WAEMU). These surveys were carried out by the National Institutes of Statistics in these countries in 1996. The main objective of these investigations was to evaluate, in a multilateral way, economic performance through the determination of weights for calculating Harmonized Consumer Price Indices (HCPI). They were carried out in collaboration

with a team of experts of the National Institute of Statistics and Economic Surveys of France (INSEE) and experts of EuroCost. The sample size was fixed at 1008 households (INSD, 1998). The investigation took place from March 12 to June 6, 1996 (op.cit., 1998). The data collected relate to the characteristics of the households and their consumption's expenditures. Energy consumption is used here for households annual expenditure, mainly for cooking meals, expressed in CFA francs. Also, for each energy source, the household energy consumption is the annual expenditure for the purchase of this energy source.

The figure 1 illustrates household cooking energy use in Ouagadougou for 1996 compared to 2007.

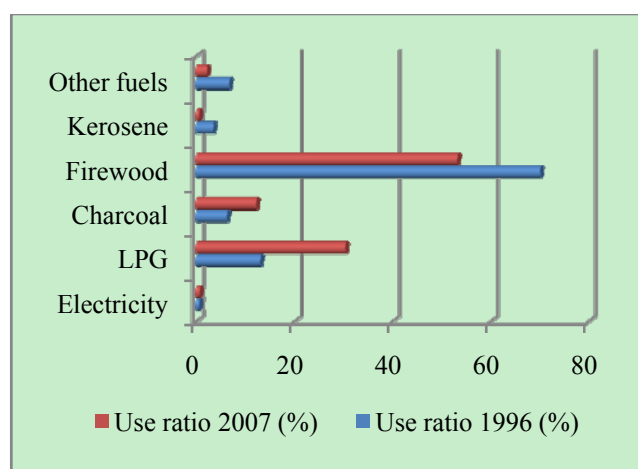


FIG. 1 HOUSEHOLD COOKING FUELS USE IN OUAGADOUGOU

The dominating source of household cooking energy in Ouagadougou in 1996 was wood-energy which is used by 76.3% of the households; 70.1% mainly use firewood and 6.2% charcoal. LPG is this city's second most preferred source of household energy with 13% of the population using it on a daily basis. Kerosene is used by 3.4% of the households and only 0.6% use electricity for cooking. 6.7% of the households use other solid fuels such as concentrates of agricultural residue and animal waste (cow dung). The last national survey on households' living conditions (INSD, 2007) let us observe a change for households' cooking energy use in the Ouagadougou area: 53.2% for firewood, 12.2% for charcoal, 0.6% for kerosene, 30.4% for LPG, 0.7% for electricity and 2.1% for other fuels. However, fuelwood remains the dominating cooking fuel for these urban households.

Figures 2 and 3 examine the supposed links between the domestic uses of various sources of cooking energy in Ouagadougou and the household's size and his standard of living (captured by the quintiles).

Figure 2 lets observe two differentiated tendencies of

the use rates of cooking energy when the households' income changes. The first tendency is observed on firewood use rate which decreases from poorest households to richest ones. The second tendency is observed on cooking fuels like Charcoal, kerosene, LPG and electricity whose use rates increase from poorest households to richest ones. These tendencies suppose not only a negative correlation between the firewood use rate and the standard of living of the households, but also a positive correlation between the use rates of fuels like kerosene, LPG and electricity. There is evidence to show that people in urban areas use more kerosene, LPG, and electricity. All things which let predict a transition between these two categories of energy when the standard of living of the households increases. That seems to validate the energy ladder hypothesis which is one of the most common approaches used in studying the household energy use patterns. The energy ladder hypothesis explains the movement of energy consumption from traditional sources to more sophisticated sources along an imaginative ladder with the improvement in the economic (income) status of households (Masera et al., 2000 ; Rajmohan and Weerahewa, 2007). It states that people with low incomes generally use traditional fuels as their main cooking fuel and people with higher incomes tend to use modern fuels.

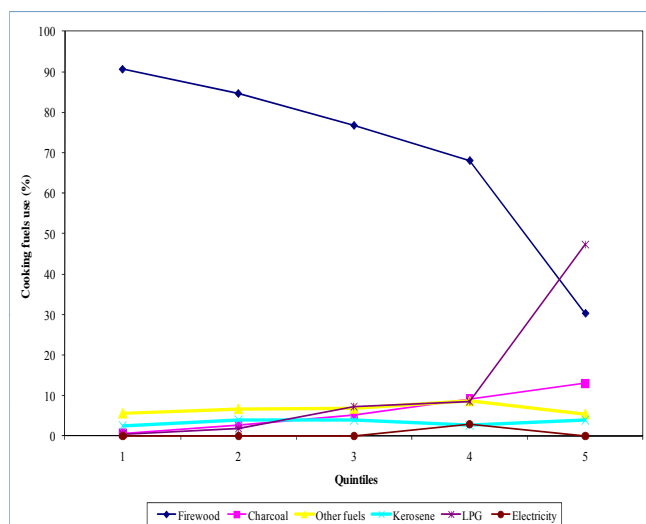


FIG. 2 COOKING FUELS USE RATE AND HOUSEHOLDS' STANDARD OF LIVING

Results of the energy demand studies reveal that the income, fuel prices, government policies and household characteristics influence energy consumption levels. They also suggest that price-based and quantity-based government policies tend to influence the urban fuel demand patterns more than does the household income level (Bhatia, 1988). Figure 3 aims at showing how the cooking energy use rates could be affected by

the size of the urban households of Ouagadougou.

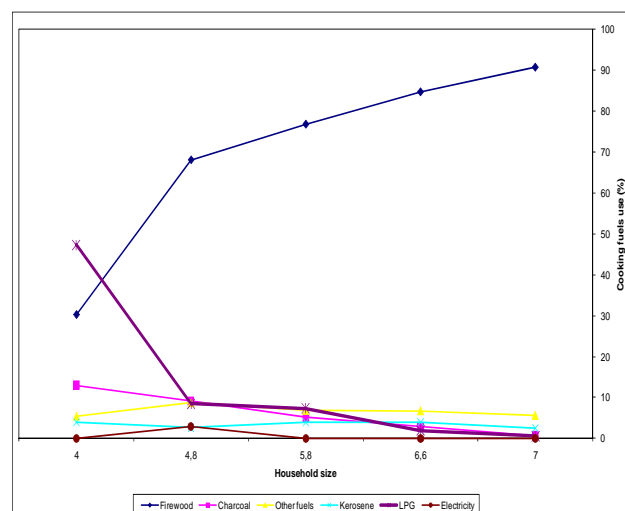


FIG. 3 HOUSEHOLD COOKING FUELS AND HOUSEHOLDS' SIZE

Figure 3 takes two differentiated forms between the use rates of the various sources of cooking energy when the size of the household increases. In the one side, we observe the firewood of which the use rate among the households increases when the size of the households increases, letting suppose that the households having the largest sizes are those who are the firewood biggest users. In the other side, the use rates of cooking fuels like the charcoal, kerosene, LPG and electricity drop when the size of the households increases. One could say that this category of cooking energies is preferred by the households of small size. The most remarkable example of this category of energies is that the LPG whose curve's slope is strongest, indicating a possible strong negative correlation between the use rates of LPG and the size of the households.

### Empirical Analysis of the Demands' System and Policy Analysis

The estimation of Engel curves of different concerned goods gives the  $\beta_i$  coefficients (outcomes from equation (2)) which are used for computing the expenditure or budget elasticities ( $\eta_i$ ) outcomes from equation (3), and the impact of household characteristics. The procedure of estimation was the "iterative weighted least squares", ie a combination of maximum likelihood and weighted least squares. The results are obtained in the second iteration. The parameters are estimated from the overall system of eight equations with three unknowns each with a constant. Engle curves are estimated for firewood, charcoal, kerosene and LPG simultaneously together with food and non food goods. The semi- logarithmic model is regarded



to be the best suit for empirical estimations of Engle functions (Prais and Houthakker, 1955). The statistical software used for the estimation was E-Views version 5. These results are given in table 1.

Electricity demand function is exclude from model because less than 0.6% of the household of this city use the power source as cooking fuel.

### Checking Ex-post of the Theoretical Restrictions

The estimated parameters of AIDS model are constrained to some restrictions which we will try to check:

1- The sum of constants ( $\alpha_i$ ) for each equation of the demand system is equal to 1:  $\sum \alpha_i = 1$

2- The sum of  $\beta_i$  is equal to 0:  $\sum \beta_i = 0$ .

3- The Engel's aggregation principle:

$$\sum_i p_i \frac{\partial q_i}{\partial y} = \sum_i w_i \eta_i = 0,999999 \cong 1$$

$$\text{where } w_i = \frac{p_i q_i}{y} \text{ are the budget shares.}$$

4- The symmetry assumption:

The constraint of symmetry is imposed in the estimate of all model AIDS.

### Model Goodness of Fit

The estimation of the model parameters is based on the Engel curves, so the test of the model validity will be also based on that of the Engel curves. The significativity and the validity of the model parameters are really a question which touches with

the confidence which one has the right to place in forecasts based on the analysis of a given sample of actual values. The measurement of the model's overall goodness of fit (adequacy) is based on the value of the  $R^2$ , which is the ratio between the explained variation and the total variation of the dependent variable. In the case of the time series, the adjusted  $R^2$  value must be at least equal to 50% to claim to have a good adequacy of the estimated model. We used cross-sectional data and thus we obtained adjusted  $R^2$  which values are not high: on eight estimated Engel curves, we obtained adjusted  $R^2$  whose values are respectively of 1% for charcoal, of 15% for firewood, of 10% for the LPG, of 18% for kerosene, of 9% for food goods, of 17% respectively for local cereals (maize, sorghum, millet) and rice (imported one), and 35% for the non-food goods. In the major part of the empirical studies using this type of data, the value of these adjusted  $R^2$  would attest a good adequacy of the model, if and only if the individual coefficients are significant. It is the case of alcohol and tobacco budget shares' modelling carried out on the Belgian households where  $R^2$  are very weak (about 5% and 15%), but which effectively explain the behaviour of the households compared to the income (Marno Verbeek, 2000) and that of Wooldridge (2000, page 40) on the wages with a  $R^2$  of about a 1,3% but with very significant parameters, with a good explanatory capacity of the studied phenomenon. The same trend for  $R^2$  or adjusted  $R^2$  are found in the studies of Gebreegziabher, Oskam and Bayou (2010) with adjusted  $R^2$  between 0.067 and 0.215 for firewood, charcoal, kerosene and electricity demands, that of Rajmohan and Weerahewa (2007) where the adjusted  $R^2$  were between

TABLE 1 ECONOMETRIC ESTIMATES OF ENGEL FUNCTIONS

Goods or groups of goods	Estimated parameters						Adjusted $R^2$
	Constant ( $\alpha_i$ )	Budget coefficient ( $\beta_i$ )	Illiterates	High Education level	Household size	Mean of Ln(Y)	
Firewood	0.288 (9.67)***	-0.023 (-9.86)***	0.003 (0.69)	0.009 (1.46)	0.023 (9.53)***	0.027	0.15
Charcoal	0.023 (2.79)***	-0.001 (-2.39)***	0.000 (0.02)	0.002 (0.86)	0.000 (-0.54)	0.003	0.01
LPG	0.021 (2.76)***	-0.001 (-1.69)**	-0.005 (-4.40)***	0.009 (5.20)***	-0.001 (-1.18)	0.005	0.10
Kerosene	0.062 (12.69)***	-0.005 (-12.10)***	0.002 (2.47)***	0.000 (-0.11)	0.002 (3.91)***	0.005	0.18
Local cereals	0.408 (9.29)***	-0.033 (-9.54)***	0.025 (4.38)***	0.036 (10.35)***	0.036 (10.35)***	0.056	0.17
Rice	0.366 (10.18)***	-0.027 (-9.69)***	-0.005 (-1.02)	0.021 (2.79)***	0.033 (11.32)***	0.057	0.17
Other foods	0.809 (9.15)***	-0.027 (-3.89)***	-0.018 (-1.41)	-0.093 (-5.66)***	-0.041 (-5.70)***	0.377	0.09
Other goods	-0.978 (-12.82)***	0.116 (19.63)***	-0.001 (-0.13)	0.018 (1.08)	-0.052 (-8.30)***	0.467	0.35

Notes: \*\*\*=significant at 1 % level; \*\*=significant at 5 % level; \*=significant at 10 % level. The estimation method is the « iterative weighted least squares ». [between brackets, find the t-statistics, parameters resulting from model AIDS]

Source: Estimation using the INSD-UEMOA(1996) Projet database

0.07 and 0.44 for urban Sri Lanka urban households' cooking fuels demand and that of Gundimeda and Köhlin (2006) for which the  $R^2$  of estimated Engel curves were between 0.26 and 0.46 for a very large sample. All these studies used AIDS model approach.

### 1) Model Individual Coefficients' Significance Test

We obtained the following significativity for each estimated coefficient of the explanatory variables:

- budget elasticities are all significant at maximum 5%: what is statistically very satisfactory;
- the coefficients of the variable "household's size" are all significant at 1% except those concerning the equations of the variables "charcoal", and "LPG";
- the coefficients concerning the variable "formal education level of household's head" are also all significant at maximum 10% except those concerning the equations of the "firewood" and "charcoal".

### 2) Engels Curves, Budget Elasticities and Impact of the Income on the Demand Cooking Energies

Income has been the single most important explanatory factor in the literature on the choice of domestic fuel the last two decades (Arnold, Köhlin, Persson, 2006; Gundimeda and Köhlin, 2006). It is also the basis for the energy ladder model and although this model has been elaborated lately (Masera et al, 2000; Heltberg, 2004), income, or its proxy expenditure, remains as the most important variable in explaining fuel demand. This can also be understood from figures 2, 3 and 4 that show the change in major fuel choice in urban Ouagadougou. Figure n° 4 draws the Engels functions (estimates of table n°1).

All cooking energies' Engel curves decrease while households' total expenditure increases, that suggests that these cooking energy sources are primary (necessity) goods for the households of Ouagadougou.

For the households belonging to the first twenty centiles, we observe that the budget shares of firewood are very high (between 3% to 10% of household total expenditure): the very strong slope of firewood curve between the first centile and the twentieth centile reveals a strong sensitivity of these two energy sources demand for these poorer households compared to their income level. These high budget shares of firewood for the poorest

households is critical because they show a strong dependence of these households to this traditional energy. This assumes that the firewood could be an inferior good for the poorest households, which could shift to more conventional cooking energy when they can access higher levels of living. From the twentieth centile and the 76<sup>th</sup> centile, the slope of firewood curve becomes less marked varying the budget shares from 0.04% to 3%. Beyond the 77<sup>th</sup> centile, the budget shares of firewood become negative: that suggests firewood could be shift by others cleaner energies when the households rise to higher income levels.

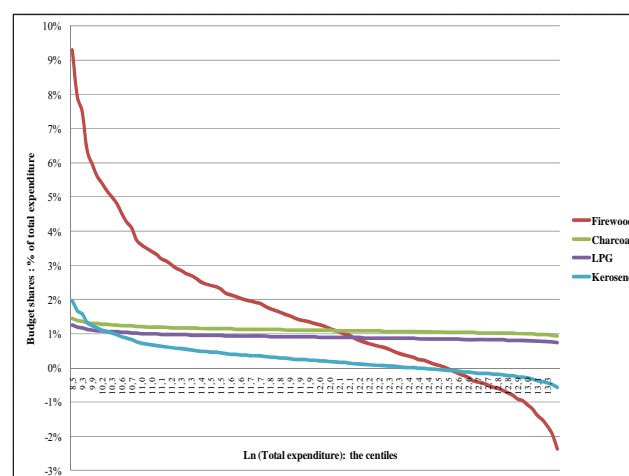


FIG. 4 ENGEL CURVES OF HOUSEHOLDS COOKING ENERGIES IN OUAGADOUGOU

The sign of  $\beta_i$  determines whether the commodities are necessities/luxuries. When  $\beta_i > 0$ , the commodity is a luxury, if  $\beta_i < 0$ , they are necessities (Gundimeda and Köhlin, 2006). The coefficients allow assessing the impact of household characteristics on budget share. Regarding to estimates of the table 1, all  $\beta_i < 0$ , so, all the cooking fuels are necessities or primary goods for urban households of Ouagadougou.

The formula of equation (3) allows computing the budget or expenditure elasticities ( $\eta_i$ ) in table 2 below.

TABLE 2 EXPENDITURE ELASTICITIES ( $\eta_i$ )

Goods or groups of goods	Expenditure (budget) elasticity ( $\eta_i$ )
Firewood	0.160***
Charcoal	0.434***
LPG	0.781**
Kerosene	0.159***
Local cereals	0.419***
Rice	0.548***
Other foods	0.929***
Other goods	1.248***

Notes: \*\*\*= significant at 1 % level; \*\*= significant at 5 % level

Table n° 2 shows that cooking energies and the food goods have budget elasticities ranging



between 0 and 1, also all these goods are primary goods suggested earlier the  $\beta_i$  coefficients in table 1. An increase in the households' total expenditure of 1% involves respective rises of 0.16% for firewood, of 0.43% for charcoal, 0.78% LPG, and the 0.16% for kerosene. For local cereals (sorghum, millet, corn), a 1% rise of the households' income involves an increase in these goods demand of 0.42%. For rice, a rise of 1% of households' income increases its demand by 0.55%. A rise of households' income of 1% involves an increase in the demand of the other food goods (breads, pastry making, biscuits, spaghetti, meat etc.) of 0.93%. However, the non-food goods have an elasticity returned higher than 1.

The previous studies (Rajmohan and Weerahewa, 2007; Gundimeda and Köhlin, 2003, 2006) also found the same trend of income impact on both urban and rural households cooking fuels demand in Sri Lanka and India suggesting that with increasing income levels people tend to use more energy efficient technologies, while reducing the total energy cost. However, Gundimeda and Köhlin (2006) found for firewood a value of expenditure elasticity higher than one suggesting that firewood demand are very responsive to income changes.

### 3) Own Price and Cross-price Elasticities of Cooking Fuels Demand

Table 3 gives to the matrix of Hicksian price elasticities for goods and groups of goods brought into play in the regression. The knowledge of monetary flexibility enables computing direct and cross-prices elasticities. Since model AIDS implies a monetary flexibility of -1, we privileged the use of a monetary flexibility of -1, in conformity with the selected model to approximate direct and cross-price elasticities.

In absolute terms, for normal goods the Hicksian own price elasticities are smaller than the Marshallian ones. The signs of own price elasticities both for uncompensated<sup>5</sup> (Marshallian from table 4 in Appendix) and compensated (Hicksian from table 3) demands, are all consistent with the economic theory. The Hicksian values in table 3 give the most accurate picture of cross-price substitution since they provide a measure of substitution effects net of income effects. These cross-prices elasticities have some potential

important policy implications given the highly regulated Burkinabe energy sector. The policies over the last two decades have meant implicit or explicit subsidies of fuelwood through the plantation programs, the promotion of more efficient cook stoves with firewood, the promotion of LPG storage bottles and appliances; there is also the LPG consumer price which subsidized at 33% of its kilogram price (Ouedraogo, 2002). This LPG subsidy is fixed to 32% in India (Gundimeda and Köhlin, 2006)

TABLE 3 THE MATRIX OF HICKSIAN (COMPENSATED) DEMANDS' DIRECT AND CROSS-PRICE ELASTICITIES

Goods	Energy for cooking				Food and non-food goods			
	Firewood	Charcoal	LPG	Kerosene	Local cereals	imported and local rice	Other food	Non food
Firewood	<b>-0.206</b>							
Charcoal	0.003	<b>-0.447</b>						
LPG	0.004	0.001	<b>-0.754</b>					
Kerosene	0.001	0.000	0.001	<b>-0.150</b>				
Local cereals	0.003	0.001	0.002	0.000	<b>-0.445</b>			
Imported local rice	0.003	0.001	0.002	0.001	0.015	<b>-0.569</b>		
Other food	0.005	0.001	0.003	0.001	0.023	0.032	<b>-0.600</b>	
Non food	0.007	0.002	0.004	0.001	0.032	0.044	0.431	<b>-0.521</b>

Sources: IPHPC-UEMOA/INSD database (1998)

A rise of the prices of these fuels of 1% involves respective falls of the demand for these energies of 0.206% for firewood, 0.447% for charcoal, 0.754% for LPG and 0.150% for kerosene. LPG has the most responsive demand. Households' demand for cooking energies is not responsive to their own prices since a variation of these prices involves a lower variation of the demand for these energies. Three main reasons could explain that insensitivity of cooking fuels demand to fuels own prices; first, the great dependency of poorest households to firewood; secondly, the very weak relative price of firewood compared to those of cleaner fuels like LPG and power; and third, the costly of LPG and electricity cooking supports (LPG storage bottles, cook stoves, apparatus). However that does not mean that a pricing policy of cooking energies is not possible on the level of the households. As a whole, this inelasticity of the demand is confirmed compared to the socio-economic nature of these energies which are all necessities for the households of this city. The demands for these energies are far from sensitive to the variations of

<sup>5</sup> See Marshallian demand elasticities in Table in Appendix

their own price. The LPG demand is most sensitive to the variations of its price compared to the other cooking fuels' demand, its direct price elasticity's coefficient being highest. The conclusion is that cooking fuels' demand is relatively inelastic compared to their own price.

The positive sign of Hicksian cross-price elasticities shows a substitution relation between energies considered while the negative sign indicates a relation of complementarity. On the basis of compensated system of demands estimated (Hicksian demands in table 3), we observed substitution's relations between various cooking fuels since the sign of their cross-price elasticity coefficients are positive. The expected substitution relations between wood-energy and the LPG appeared and confirmed. The values of these elasticities being very weak, we observe weak substitution effects compared to a variation of the price of one of the substitutes. For example an increase of 1% of the prices of the LPG involves only one rise of 0.004% of the budget shares of the firewood. The low values of these elasticities are undoubtedly explained by the strong separability assumption that is used for the calculation of these elasticities: cooking energies having been considered individually inducing very weak budget shares for these energies compared to those of the groups of goods, implying a very low value of elasticities for the ones and a higher value for the others. Although there is a relation of substitution between woodfuel and the other sources of energy of cooking (in particular the LPG which proved to be the main substitute) and in spite of the subsidy of the price to the consumer of gas, the impact of the policy of substitution by LPG remains very negligible for the following reasons: a) very low sensitivity of the demand of wood-energy compared to its own price; b) very low sensitivity of LPG demand compared to its own price; c) high costs of LPG cooking supports (hearths with LPG, LPG storage bottles). For example, the operation Boomerang initiated by the Distributive firm of LPG (SODIGAZ) in 1995 which consisted of a sale promotion of LPG storage bottles (1000 bottles) in Ouagadougou, contributed to raise the demand for this fuel of almost 34% the year which followed. This operation shows that the acquisition's cost of the LPG cooking supports (hearths with LPG, LPG storage bottles) is a barrier to the promotion of its use, therefore with the substitution of wood-energy. Other factors not less negligible contribute to amplify the failures of the

pricing policies of wood-energy. Among these constraining factors, there is the size of the household which positively determines the demand of the firewood while affecting negatively the LPG demand. While the educational level of household's head is a barrier to the use of kerosene, it constitutes an incentive for LPG use, but has no significant impact on the use of firewood.

## Conclusions and Policy Implications

Analysis by the households' complete system of demands results from cooking energies' demands which are primary goods since their income elasticities are lower than one. Given their importance for households welfare, public investments and environmental considerations, it is surprising that not more formal studies have been carried out for Sub-Saharan African countries to analyse income, own price and cross-price elasticities of demand for a full set of domestic energy sources, including fuelwood. The proliferation of national sample surveys must help to address this gap. In this paper we have shown that the Burkina Faso National Institute of Statistics and Demography data, that include households expenditures can be used for this purpose.

It is very important to note that the energy consumption for households is their final consumption only for cooking meals and various heaters other than commercial consumption.

The results from this study can be used in many ways depending on the policy objective in mind. For a country like Burkina Faso, with government interventions that affect the price of domestic fuels, the impact of such interventions on demand can be analysed based on own- and cross-price elasticities of demand. Similarly, if the desired policy objective is transition towards clean fuels (like LPG mainly in Burkina) due to the health impacts or local and global pollution, then these elasticities can prove useful in identifying the most cost-efficient policy. In this specific case where firewood remains the main cooking fuel for urban population of the capital city of this country, there are at least two environmental arguments to decrease fuelwood use through subsidies of close substitute (Gundimeda and Köhlin, 2006). The first one claims that fuelwood collection leads to deforestation. The second is the evidence that low-grade fuels lead to indoor air pollution that is associated with a number of diseases (Kammen, 1995; Smith, 2005; Heltberg, 2005). Although the cooking fuels cross-price elasticities coefficients are very low,

their comparison allows identifying the main cible of a substitution policy: here LPG have the greatest value of cross-price elasticity compared to firewood, so remains the main substitut of woodfuel.

Another area of application is similation for energy planning. For policy conception and implementation, there is a necessity for energy planning exercices that could be made more realistic and accurate if they are based on the kind of analysis provided in this paper.

The households' income determines significantly the wood-energy demand for cooking in Ouagadougou. Athukorala and al. (2007) in estimating the household demand for electricity in Sri Lanka found that electricity is a normal good and has inelastic demand in the Kandy area. Gebreegziabher, Oskam and Bayou (2010) in their study, have used an AIDS approuch to investigate urban household fuel demand in Ethiopia and found negative and very low value for firewood, charcoal and kerosene  $\beta_i$  coefficients showing that firewood, charcoal and kerosene are necessity goods for urban households in Ethiopia: that negative values indicate that these fuels budget shares go down when households' income increases.

In the case of urban households fuels demand in Ouagadougou, the demand for these energies are relatively inelastic, and thus remain not very responsive to these fuels own prices. The primary goods are naturally of a very weak demand price elasticity; this low response of the demand for these goods compared to their own price holds of the primary character of these goods in the nature of the needs for the households and confirms the strong dependence of these households to these goods, in particular for the charcoal and firewood for which direct elasticities price are lowest. The same tendency is found in the studies of Gebregziabher and al. (2010) and Hyde and Köhlin (2000) with very low own price elasticities for households firewood demand for cooking while Gundimeda and Köhlin (2006) found very higher value for own price elasticity and very responsive firewood demand both for uncompensated and compensated demand. For Gundimeda and Köhlin (2006), this higher<sup>6</sup> responsiveness of firewood demand compared to it price is due to increasingly fuelwood cost and very costly prices of alternative fuels. The wood-energy demand (firewood and

charcoal) compared to LPG presents the lowest direct price elasticities, and its cross-price elasticities compared to that of LPG are also very low: what constrained strongly wood-energy price and substitution policies. Other cooking energies are very slightly substitutable with woodfuel. That explains why the wood-energy price policies which in spite of their magnitude had only one very weak impact on the fall in the wood-energy demand and its substitution. Ouedraogo (2006b) analyzing the existence of a parallel firewood supply and an important uncontrolled or fraudulent firewood supply in the area of Ouagadougou, highlights how that parallel supply which escapes the taxes and forest royalties draws the firewood price to the bottom and thus diverts the price policies and the emergence of the private plantations of trees with energy goal. This low cost of firewood seems to plains the non responsive demand of firewood to its own price, constraining firewood's price and substitution policies.

The educational level of the heads of households, the size of the households have a significant impact on the demand of cooking energies, but are variables on which actions of short or medium terms cannot have significant impact. For this reason, they cannot be taken into account in short and medium terms' policies which appear paramount to inflect the demand for this fuel which burns nowadays the woodlands of this country. The wood-energy pricing policy as demand regulating factor is all the more inoperative as the domestic demand of wood-energy proved to be inelastic and households to be strongly dependant from firewood and charcoal. However, the wood-energy pricing policies which strongly index the scarcity of the woody resource to the consumers, if they are accompanied by a subsidy policy by promoting the cooking's equipments with LPG and kerosene (cook stoves, apparatus, LPG bottles, solar energy's cook stoves) and connection with the electric power, could favour a greater use of these alternatives.

There are still a number of improvements that could be made to this approach. Cross-sectional data are notoriously difficult to use in order to estimate price elasticities, primarily due to the lack of variation in price and the potential confounding quality effects (Deaton, 1990). Specially in this specific cas where data did not include price information and data old. For future fuel related estimations, panel data analysis is probably worth attempting combined with more flexible functional forms. Sample surveys combined with collection of fuel prices would be ideal. Such rich data sets could be used for much more disaggregated analysis than what has been made here.

<sup>6</sup> Two developpments in Indian local forest management could give rise to local fuelwood scarcity: the recent interest for using forests for carbon sequestration and the local forest protection by joint forest management.

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## Author Biography

Boukary Ouedraogo was born on September 2<sup>nd</sup> 1969 in Ouahigouya (Burkina Faso). He received his "BACCALAUREAT" in 1990 and enrolled in the School of Economics and Management at the University of Ouagadougou (Burkina Faso) where he obtained his "Maîtrise" in Private Enterprises Management (1994) and his Master diplomas in Industrial economics (1996). After coordinating a research program at the Centre for Documentation and Economic and Social Research of the University of Ouagadougou (1998-1999), he enrolled in the Ph.D. thesis at the University of Montesquieu Bordeaux 4 (France) where he obtained in 2002 his Ph.D in Economics. It is part of the University of Ouagadougou as professor assistant in September 2002. January 17, 2011, he obtained a Ph.D. in Education Sciences with the University of Montreal (Canada). He is now Associate Professor at University Ouaga2 (Burkina Faso).

## Appendix

TABLE 1 MARSHALLIAN MATRIX OF PRICE ELASTICITIES

Goods	Energy for cooking				Food and non-food goods			
	Firewood	Charcoal	LPG	Kerosene	Local cereals	imported and local rice	Other food	Non food
Firewood	<b>-0.2116</b>							
Charcoal	-0.0096	<b>-0.4480</b>						
LPG	-0.0162	-0.0011	<b>-0.7575</b>					
Kerosene	-0.0032	-0.0002	-0.0002	<b>-0.1508</b>				
Local cereals	-0.0098	-0.0007	-0.0005	-0.0021	<b>-0.4702</b>			
Imported and local rice	-0.0127	-0.0009	-0.0007	-0.0027	-0.0179	<b>-0.6040</b>		
Other food	-0.0197	-0.0013	-0.0010	-0.0043	-0.0279	-0.0225	<b>-0.9473</b>	
Non food	-0.0267	-0.0018	-0.0014	-0.0058	-0.0378	-0.0305	-0.0378	<b>-1.1021</b>

The price elasticities are computed from income elasticities, budget shares, and money flexibility of value -1 which is an internal constraint of AIDS model.  
Sources : IPHPC-UEMOA/INSD database (1998)